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URBANA

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PETROLOGY AND SEDIMENTATION OF UPPER
CHESTER SANDSTONES

BY
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PETROLOGY AND SEDIMENTATION OF UPPER CHESTER SANDSTONES¹

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ABSTRACT

A study of the mineral constituents and textures of upper Chester sandstones in Illinois was undertaken to throw light on environments of deposition, tectonic activity, and possible source areas. Although there are many minor facies changes in all the sandstone beds, all except the Menard and Kinkaid sandstones are persistent over wide areas in the Eastern Interior Basin. Most of the sandstone beds are dominantly quartzose, with minor admixtures of clay minerals, carbonate, rock fragments, and accessory minerals. Most of the sandstones are well-sorted clean orthoquartzites, but many sandstones have a composition more like that of a subgreywacke. Many of the sands show evidence of having been winnowed and reworked at the site of deposition. The sedimentary environment is reconstructed from petrographic and stratigraphic data as dominantly sublittoral, near-shore, with brackish or marine waters, although there is evidence that some of the sands were deposited on a terrestrial coastal plain. The mineral composition of the sands, considered in conjunction with the amounts of coarse clastic material in other areas of deposition during Chester time, points to northern sources of detritus rather than sources to the east.

This investigation is concerned with the sandstones of the upper half of the Chester series (Upper Mississippian) in the Eastern Interior Basin. This basin, which persisted through much of the Paleozoic era, covers much of Illinois and adjacent parts of Indiana and Kentucky. In this area Chester stratigraphy has been worked out in great detail, both from outcrop and subsurface studies (Weller & Sutton, 1940; Workman, 1940).

The purpose of this study is threefold: (1) to determine petrographically the provenance, or source, of the detritus which makes up the clastic portion of these rocks; (2) to determine the general characteristics of the sedimentary and tectonic environment in which the rocks were formed; and (3) to relate the sedimentary petrography of the rocks to the details of sedimentary structure and stratigraphy. This paper presents the first results of a long-range study of the petrography and origin of the clastic Paleozoic sediments in the Eastern Interior Basin.

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STRATIGRAPHY

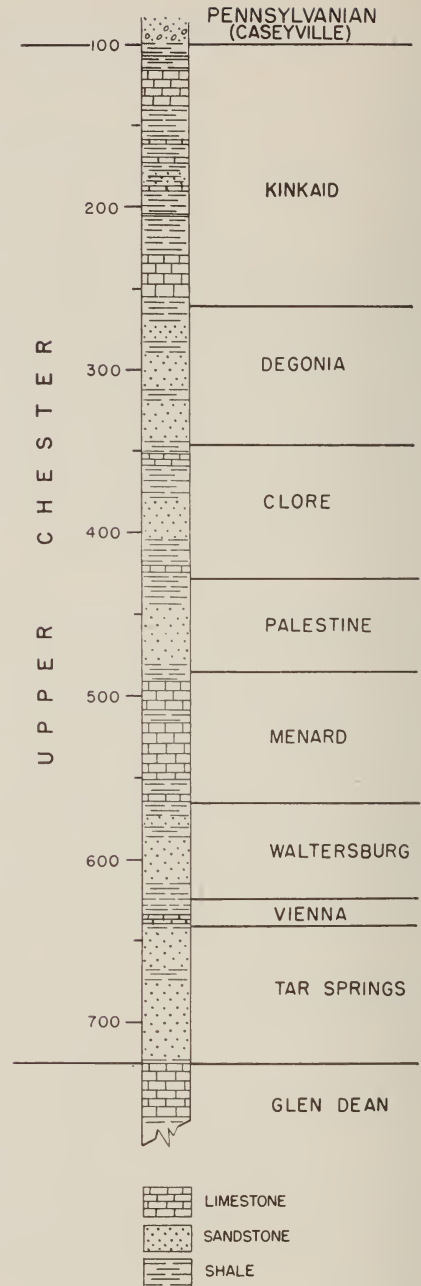
The general character of the Chester succession in the Eastern Interior Basin is that of a thick transition zone of mixed carbonate and clastic rocks lying above the dominantly carbonate rocks of the Lower Mississippian and below the dominantly clastic rocks of the Pennsylvanian. Stuart Weller (1920) was the first to divide the Chester series into 16 alternating sandstone and limestone-shale formations and to point to the cyclical character of the sediments (fig. 1). Cyclicity is suggested not only by repeated lithologic alternations but by unconformities at the bases of the sandstones, which have been thought to be largely nonmarine. Thus each limestone-shale formation may be paired with an underlying sandstone formation, each pair separated by an unconformity. Thin coal beds at the top of some of the sandstones increase the resemblance to the cyclical units in the Illinois Pennsylvanian, which J. M. Weller (1930) has described.

The abundant subsurface information which has become available in recent years has shown that, although the cycle

concept still holds as a generalization, qualifications must be added that complicate the picture. In some areas the mixture of shale, sandstone, and limestone in the various formations is distributed vertically in such a way that any generalization as to repetitive order of beds is impossible. A study of the sub-surface sections shows that shales are associated not only with limestone beds but just as abundantly with sandstone beds. Further, there are several relatively persistent sandstones associated with limestone beds.

One interpretation of the cyclical sequence is that there was a constant influx of shaly material intermittently diluted with quartz sand. During periods when quartz sand was supplied from the source area, more or less argillaceous sands were deposited. During periods of greater stability, when there was little available quartz sand, shales and limestones were deposited. There may have been no great difference between the sedimentary environmental conditions for these different types of deposits; rather there was a difference in the degree of tectonism of the source area and therefore of the kind of detritus supplied.

Extreme lateral variation in lithology and thickness of sandstone and shale beds is a striking feature of the Chester series, just as it is of the overlying Pennsylvanian (fig. 2). Sandstones may grade laterally into shale within a distance of a mile or less. This is the dominant type of local stratigraphic variation. In general, the limestone beds are more uniform in thickness over wide areas. Superimposed on this local variation are regional facies changes, such as Swann (1948) has discussed, involving thickness and lithology of beds and the numbers and kinds of members of the formations. Swann (1951) made a valuable delineation of the lateral variation of one Chester sandstone, the Waltersburg. His maps show that Waltersburg sand bodies are definitely linear and are uniformly oriented northeast-southwest. The significance of the shapes of these sand bodies is discussed below.



ILLINOIS STATE GEOLOGICAL SURVEY

FIG. 1.—Generalized section of upper Chester formations in Illinois (after Siever, 1951).

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300'
200'
100'
0'
-100'
-200'



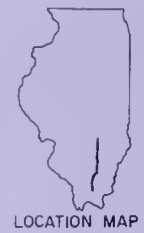
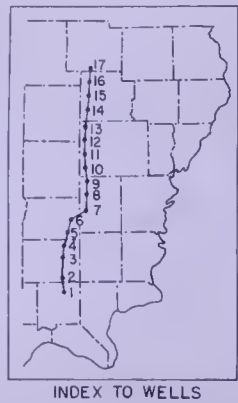
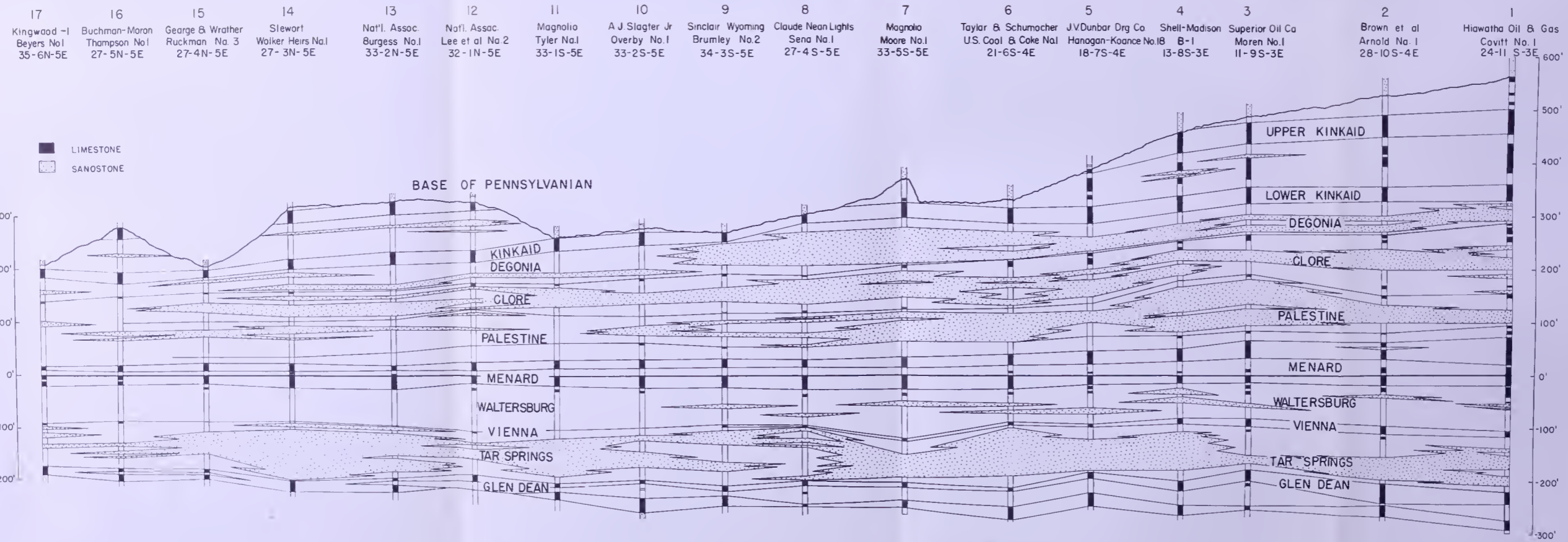


FIG. 2.—North-south cross section of upper Chester strata in Illinois.

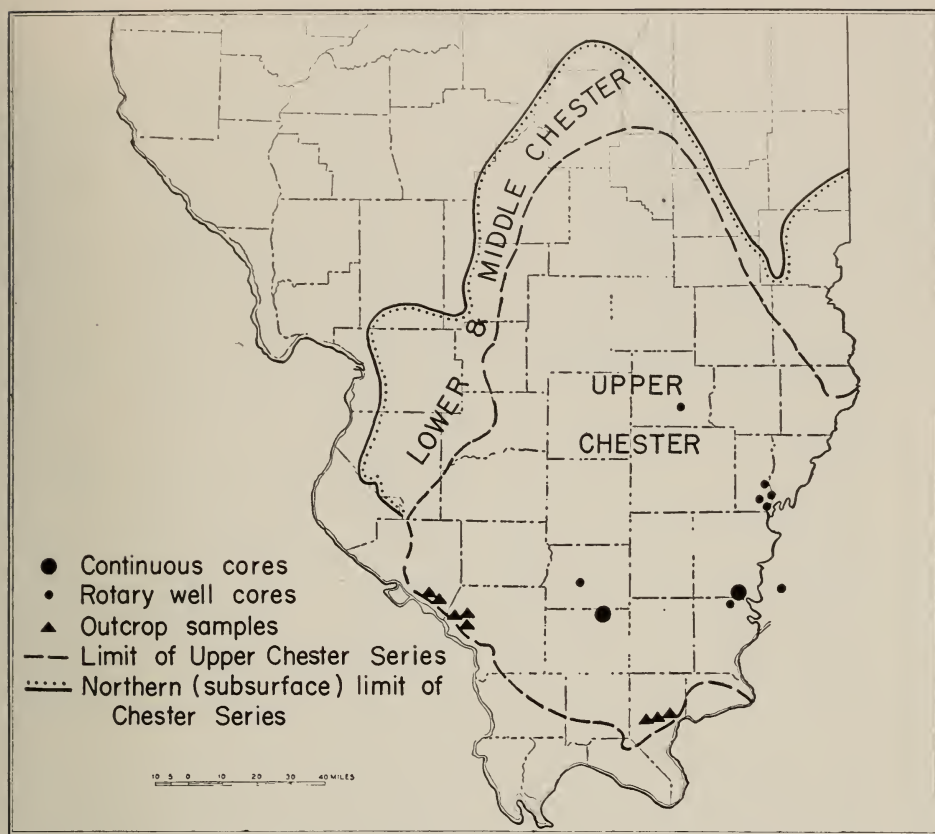


FIG. 3.—Distribution of upper Chester sandstone samples (Indiana samples not shown).

SEDIMENTARY PETROGRAPHY

Some of the samples chosen from upper Chester formations come from outcrops in southwestern Illinois near the type areas of many Chester formations. Some were collected in southeastern Illinois and in Perry County, Indiana. The other samples come from two continuous diamond drill cores taken in White and Williamson counties, Illinois, and scattered cores from rotary drill holes in various parts of the Illinois Basin (fig. 3). Mineral composition, estimates of size distributions, and roundness of grains were determined from study of thin-sections. Clay minerals were identified tentatively by optical means and checked by differential thermal analysis and X-

ray diffraction.

The sandstones of the upper Chester series are variously bedded, from thinly laminated to massive. Bedding is a function of grain size variation and mineral composition, most commonly the mixing of varying amounts of clay minerals with quartz sand particles. Although many sandstone and siltstone beds are thinly laminated, rock sequences do not show graded bedding. Cross-bedding of several types is commonly present and ripple marks are prominent on many surfaces. Slump structures, such as contorted and convoluted bedding, and small slips or "micro-faults" are present but not common.

The detrital quartz fragments range

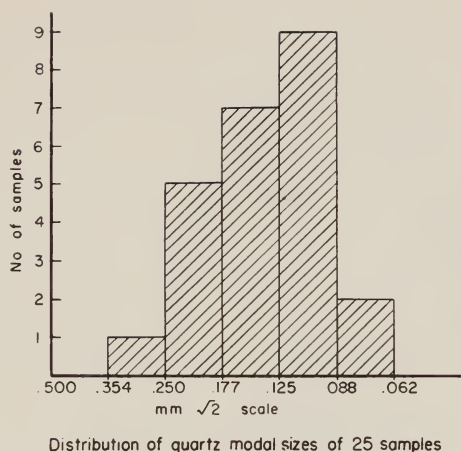


FIG. 4.—Distribution of modal sizes of upper Chester samples.

from fine silt to coarse sand in size. However, the dominant fraction of the grains falls into the finer grades of sand. Only three of the measured samples showed any grains of coarse size, greater than 0.5 mm. The modal sizes, with few exceptions, fall into the fine and very fine sand grades, averaging 0.14 mm. The distribution of the modal sizes of 25 samples is shown in figure 4. For the most part the size ranges indicate well-sorted sands. About 80 percent of the sand in most of the samples covers a range of only 4 or 5 ϕ grades. There is little variation of size distribution with stratigraphic position in upper Chester strata; rather the variation of size distribution is linked with mineralogy and texture. For example, the very calcareous sandstones are typically coarser-grained than the very argillaceous sandstones.

The roundness of the original detrital grains, not to be confused with apparent roundness of grains which have been secondarily enlarged, shows slight variation. The roundness, estimated by the visual roundness chart of Krumbein (1941), is in the range from 0.4 to 0.6 with a few samples showing averages up to 0.7. Thus, almost all the grains are rounded or well-rounded according to the classification proposed by Pettijohn

(1949, p. 51). No attempt was made to measure sphericity of grains.

The mineral composition of these sandstones is one of the most important keys to their origin. Table 1 summarizes the mineral composition of 25 samples. Quartz ranges from 63 to 97 per cent. Clay minerals vary from a trace to 30 per cent. Carbonate minerals vary from a trace to 34 per cent. Many other minerals are found in small amounts. Argillaceous rock fragments are present in almost all the samples in small amounts. Chert fragments average about 2 to 3 per cent, although they make up as much as 10 per cent of some samples. Feldspar is present in almost all the samples but rarely exceeds 1 per cent, and the highest abundance measured was 5 per cent.

Several varieties of detrital quartz have been distinguished in the thin-sections. The most abundant variety is strain-free quartz, with planes of liquid and gas inclusions, which is of ultimate igneous derivation. Quartz of metamorphic origin, either showing extreme strain shadows or consisting of a mosaic of many small intergrown crystals, does not exceed 10 per cent of the total quartz except in the samples coming from the Indiana outcrop section, where these varieties constitute as much as 25 per cent of the total quartz.

Another variety of quartz found in almost all the sections is sedimentary or reworked quartz grains. These grains show a primary detrital grain which has been rounded, secondarily enlarged, and then rounded again, indicating erosion from a preexisting sediment in which secondary enlargement took place. It is difficult to assess the significance of the various igneous and metamorphic quartz varieties in terms of their immediate derivation from an igneous, metamorphic, or sedimentary terrain. Probably many of the igneous and metamorphic grains are actually second-cycle grains, but they do not have dusty boundaries which would indicate rounded secondary overgrowths and identify them as such.

The small amount of feldspar in these

TABLE 1.—Petrographic analyses of 25 upper Chester sandstones
(in per cent by volume)

Sample No.	Stratigraphic position	Quartz	Clay	Car-bonate	Chert	Feld-spar	Quartz size		Round-ness
							Mode	Range	
54	Kinkaid	71	20	4	3	tr.	.10	.04-.22	.6
51	Degonia	89	6	0	2	tr.	.10	.02-.18	.4
52	Degonia	70	10	0	10	5	.15	.02-.30	.5
53	Degonia (lower)	92	5	0	2	tr.	.14	.03-.28	.5
4-284	Degonia (upper)	79	8	7	2	2	.10	.05-.23	.5
30	Degonia (upper)	82	7	4	4	tr.	.25	.06-.50	.5
31	Degonia (middle)	88	6	1	2	tr.	.10	.04-.23	.4+
32	Degonia (lower)	76	tr.	23	tr.	tr.	.30	.10-.50	.7
4-300	Clore	90	4	3	3	tr.	.18	.06-.35	.4+
33	Clore (upper)	65	30	3	tr.	tr.	.10	.06-.30	.4+
34	Clore (lower)	87	4	3	2	tr.	.10	.04-.20	.4
55	Palestine	95	2	0	2	tr.	.10	.03-.25	.5
56	Palestine	91	1	3	1	tr.	.10	.04-.20	.4
4-326	Palestine (middle)	97	0	2	tr.	tr.	.20	.02-.35	.6
C1319A	Palestine	95	2	3	tr.	tr.	.25	.04-.35	.5
35	Palestine	88	10	1	1	tr.	.05	.02-.14	.3
4-334	Palestine (lower)	63	tr.	34	1	tr.	.25	.10-.60	.7+
36	Menard (upper)	75	11	10	2	1	.07	.03-.13	.4
665	Waltersburg	93	2	2	3	tr.	.16	.03-.38	.5
37	Waltersburg	75	15	5	tr.	tr.	.08	.01-.10	.4
C1488	Waltersburg	95	tr.	0	2	1	.14	.04-.34	.5
C2179	Tar Springs	80	10	1	2	1	.13	.06-.20	.6
C1803	Tar Springs	86	7	1	1	1	.15	.04-.30	.6
C1974	Tar Springs	90	6	1	1	2	.10	.05-.20	.4
C1427	Tar Springs	95	1	2	2	0	.14	.03-.21	.6
Average of 25 samples		84	7	5	2	.5	.14		.5

Location of samples:

- 30. Madison Coal Co. Hole No. 25, sec. 12, T. 8 S., R. 3 E., Williamson County, Ill. Depth 1802'
- 31. Madison Coal Co. Hole No. 25, sec. 12, T. 8 S., R. 3 E., Williamson County, Ill. Depth 1833'
- 32. Madison Coal Co. Hole No. 25, sec. 12, T. 8 S., R. 3 E., Williamson County, Ill. Depth 1840'
- 33. Madison Coal Co. Hole No. 25, sec. 12, T. 8 S., R. 3 E., Williamson County, Ill. Depth 1882'
- 34. Madison Coal Co. Hole No. 25, sec. 12, T. 8 S., R. 3 E., Williamson County, Ill. Depth 1910'
- 35. Madison Coal Co. Hole No. 25, sec. 12, T. 8 S., R. 3 E., Williamson County, Ill. Depth 1959'
- 36. Madison Coal Co. Hole No. 25, sec. 12, T. 8 S., R. 3 E., Williamson County, Ill. Depth 2008'
- 37. Madison Coal Co. Hole No. 25, sec. 12, T. 8 S., R. 3 E., Williamson County, Ill. Depth 2133'
- 51. Mississippi River Bluff, sec. 24, T. 8 S., R. 5 W., Jackson Co., Ill.
- 52. Courcier Hill, Sec. 11, T. 5 S., R. 1 W., Perry County, Indiana
- 53. Courcier Hill, sec. 11, T. 5 S., R. 1 W., Perry County, Indiana
- 54. Magnolia Oil Co.—#12 Armbruster, sec. 13, T. 7 S., R. 14 W., Posey County, Indiana. Depth 1640'
- 55. Mississippi River Bluff, sec. 24, T. 8 S., R. 5 W., Jackson County, Ill.
- 56. Creek bed, sec. 3, T. 8 S., R. 6 W., Randolph County, Ill.
- 4-284. New Haven Core, sec. 18, T. 7 S., R. 10 E., White County, Ill. Depth 1913'
- 4-300. New Haven Core, sec. 18, T. 7 S., R. 10 E., White County, Ill. Depth 1974'
- 4-326. New Haven Core, sec. 18, T. 7 S., R. 10 E., White County, Ill. Depth 2086'
- 4-334. New Haven Core, sec. 18, T. 7 S., R. 10 E., White County, Ill. Depth 2136'
- 665. Carter Oil Co.—#1 Fuller, sec. 11, T. 7 S., R. 8 E., White County, Ill. Depth 2166'

- C1319A. Superior Oil Co.—#1A Blood, sec. 1, T. 3 S., R. 10 E., Edwards County, Ill. Depth 2176'
- C1427. Adkins Oil Co.—#1 Chi., Wilmington, and Franklin Coal Co., sec. 36, T. 6 S., R. 2 E. Franklin Co., Ill. Depth 2098'
- C1488. Magnolia Oil Co.—#1 Stanhope, sec. 6, T. 2 S., R. 14 W., Edwards County, Ill. Depth 2296'
- C1803. Magnolia Oil Co.—#3B Rotramel, sec. 26, T. 2 S., R. 14 W., Edwards County, Ill. Depth 2186'
- C1974. Texas Oil Co.—#1 Stanford, sec. 22, T. 3 N., R. 7 E., Clay County, Ill. Depth 2337'
- C2179. Nat'l Assoc. Pet. Co.—#1 Sanders, sec. 33, T. 7 S., R. 9 E., Gallatin County, Ill. Depth 2310'

rocks consists of both plagioclase and potash varieties. Most of these are fresh but some show extensive kaolinitization. Several authigenic feldspar overgrowths were noted on detrital rounded grains of orthoclase.

The clay mineral fractions of these sandstones, difficult to identify precisely by ordinary microscopy, were separated from the bulk of the sand by decantation and identified by differential thermal and X-ray diffraction analysis. Illite, kaolinite, and a chloritic clay mineral were found. Illite is the most abundant clay mineral in a majority of the samples and is commonly associated with the chloritic clay mineral and, in fewer cases, with kaolinite. One sample of Degonia sandstone (sample 53) showed kaolinite in greater abundance than illite. In this sample the chloritic clay mineral is also present in small amount. A sample of Kinkaid sandstone (sample 54) showed relatively high proportions of kaolinite and chloritic clay but no illite.

The association of kaolinite with chloritic clay and the absence of illite in a calcareous fossiliferous rock such as this is somewhat anomalous under normal conditions and may indicate a source of kaolinitic material (Grim, 1951, p. 230).

High relative proportions of kaolinite in association with some chlorite in these samples may indicate near-shore brackish water conditions (Glass, 1951, pp. 28–29), although it is thought that chloritic clay minerals are more characteristic of marine environments (Grim, 1951, pp. 228–9). X-ray patterns seem to indicate that some of the mica may be finely divided detrital muscovite (sericite). There is evidence from the thin-sections that some large euhedral kaolinite crystals, present in small quantity in a few samples, may be diagenetic in origin.

Although the same clay minerals, illite, a chloritic clay mineral, and kaolinite, were found in a study of Chester series shales (Grim, Bradley, and White, 1951), the relative abundances were somewhat different. In the shales chloritic clay and illite were present in higher proportions than kaolinite. This would seem to indicate that the shales sampled in this study, usually more closely associated with limestone formations, were formed in more saline waters, farther from the shore, in contrast to the more near-shore or terrestrial deposition of the sands.

Carbonate minerals, chemically precipitated rather than detrital in origin, are found in irregular patchy areas in

LEGEND FOR PLATE 1

- A. Degonia (No. 32) × 100 crossed nicols. Calcareous orthoquartzite showing calcite replacing detrital quartz and euhedral secondary quartz replacing calcite.
- B. Degonia (No. 32) × 100 crossed nicols. Calcareous orthoquartzite showing extensive replacement of detrital quartz by calcite.
- C. Clore (No. 33) × 100, plane polarized light. Shows appearance intermediate between orthoquartzite and subgreywacke.
- D. Same as C, crossed nicols.
- E. Degonia (No. 52) × 100 crossed nicols. Typical subgreywacke appearance.
- F. Kinkaid sandstone (No. 54) × 100 crossed nicols. Calcareous subgreywacke.

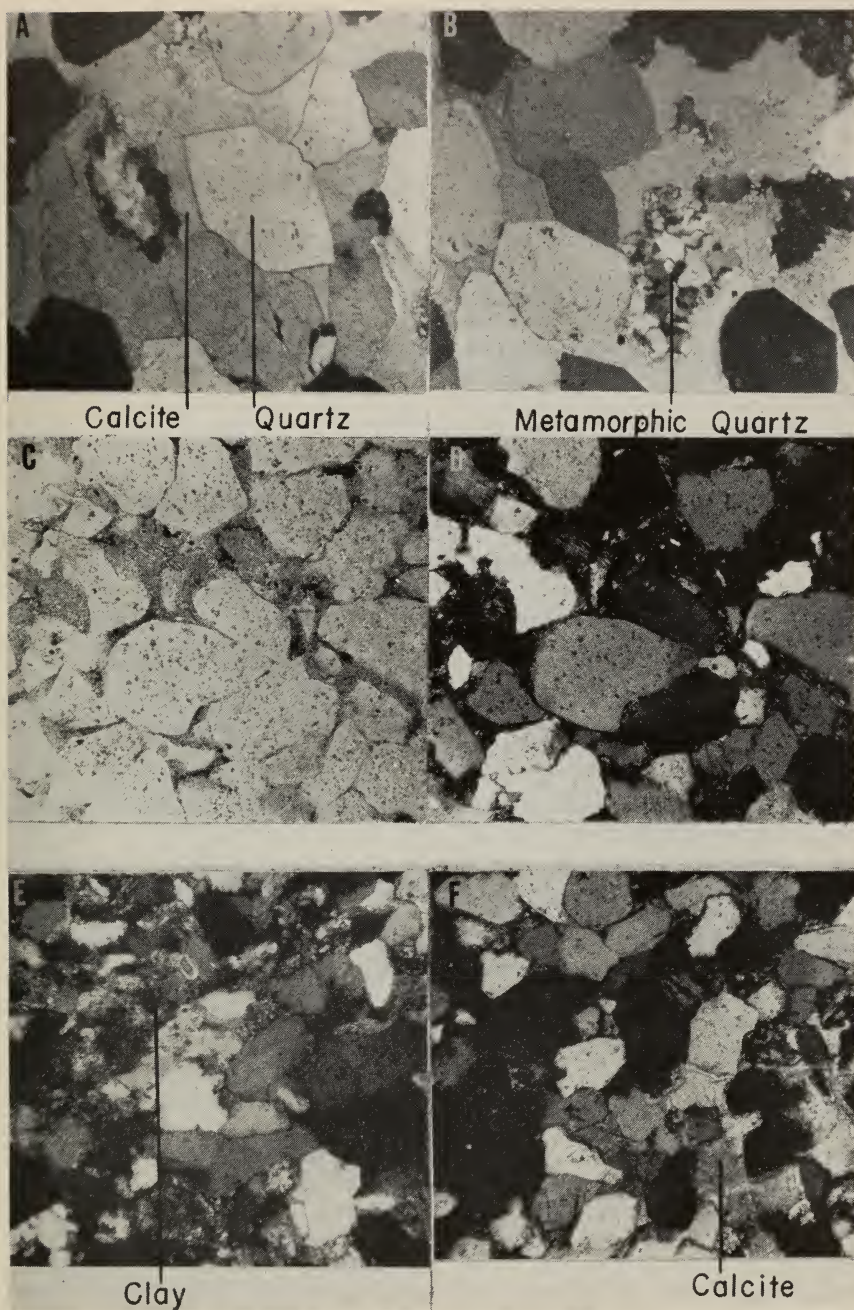


PLATE 1

Photomicrographs of Chester sandstone thin-sections.

many of the sandstones. Although most of the carbonate is calcite, some is dolomite or siderite. Carbonate occurs in the interstices and commonly replaces parts of adjacent quartz grains. Replacement phenomena, observed in thin-section, commonly follow a characteristic pattern. Carbonate replaces detrital quartz, and authigenic quartz replaces the carbonate. The chronology of cements can be interpreted from these replacements. After deposition of detrital quartz grains, calcite was precipitated in pore spaces, the calcite replacing part of the quartz. At some later time, under changed conditions, authigenic quartz was precipitated over detrital quartz grains in optical continuity with them and, in many cases, replaced some of the calcite.

Two alternative suggestions can be proposed to explain this chronology of replacement. The first is that calcite was deposited at some penecontemporaneous stage, while the unindurated sand was saturated with slightly alkaline, carbonate-saturated waters. This might be the situation while the sediment was still exposed to sea water, before burial under any appreciable thickness of later sediment. A corollary of this hypothesis would be that the amount of calcite precipitated in pore spaces would be inversely proportional to the rapidity of burial. At some later date, presumably after uplift either at the end of the Mississippian or at the end of the Paleozoic, the percolating waters changed in composition from alkaline to slightly acid, silica-saturated meteoric waters, at which time authigenic quartz was deposited and calcite was partially dissolved and replaced. The part of this hypothesis involving meteoric water infiltration should probably be rejected, partly on the evidence that the Chester sands, for the most part, contain brines that indicate that they have not been flushed out with fresh water (Meents et al., 1952).

A more reasonable hypothesis, however, can be formulated to explain the replacement of calcite by authigenic quartz. Subsequent to precipitation of cal-

cite on the sea floor and burial by later sediment, the composition of the waters in the sediments changed, as a result of lack of free mixing with aerated sea water, from alkaline and carbonate-saturated to slightly acid and silica-saturated. According to this hypothesis both replacement phenomena would have occurred very early in the diagenetic process, as a result of very slight shifts in the composition of the entrapped sea water. Testing of these hypotheses must await further studies on modern sediments, in particular the composition of interstitial waters at depth.

Heavy minerals in these sandstones are small in amount and consist of only a few species. Some 90 per cent of the non-opaque heavy minerals are zircons and tourmalines. There seems to be little variation in these minerals other than possibly different degrees of roundness and very slight color variations. No attempt was made in this study to differentiate the zircons or tourmalines on the basis of color or roundness, although it is possible that such a study would be rewarding.

Some of the samples contain organic matter. Petroleum occurs in samples taken from oil reservoirs, and carbonaceous matter, which is macerated into minute shreds and fragments, occurs in various samples. This material is presumably derived from land plants. Further evidence of land plant activity is found in the presence of stigmarian roots preserved in sandstones in certain areas.

The average mineral composition of these rocks places them between clean orthoquartzites and average subgreywackes. Many of the samples can be classed as subgreywackes by virtue of their clay and rock fragment content. The orthoquartzite aspect of some of the samples is probably due to winnowing and reworking of sands which, when deposited originally, had a high clay content. These sands are from bars or other depositional forms such as those shown on Swann's isopach maps of the Walters-

burg sandstone in the lower Wabash River valley oil fields (1951, pp. 2568-9, 2577).

SEDIMENTATION CONDITIONS

All the characteristics of upper Chester sandstones point to an environment of deposition that varied from sublittoral turbulent waters to a terrestrial coastal plain. The abrupt facies changes from shale to sandstone, the good sorting, the cross-bedding, the evidence of winnowed and reworked sand, and the lack of fauna indicate rapid changes in direction and transporting competence of turbulent currents. The abundant kaolinite and the small amount of chloritic clay in some samples may indicate incompletely saline conditions such as would be found near shore where fresh waters mixed with sea water. Samples which contain abundant chloritic clay and little kaolinite may indicate deeper water. On the other hand, it is certain that some sands were laid down in a terrestrial environment, because they contain stigmairian roots of land plants and a few autochthonous coals beds. This evidence makes it seem probable that, during the time of Chester sedimentation, the strand line must have migrated back and forth many times.

Thus there can be no generalization concerning the marine or nonmarine origin of the sands, as strata of any one time zone may be either marine, nonmarine, or both. Sands such as the Waltersburg, which show thickness accumulations suggestive of marine current origin, are most probably marine; sands such as the Palestine, which contain abundant stigmairian roots and a thin coal bed, and which have an erosional, channeled base, are more probably terrestrial.

What clues do we have as to the source areas of the sand which makes up the deposits? The varieties of quartz give some indication. Dominantly the quartz is of igneous origin, with a lesser component of metamorphic derivation. Reworked sedimentary quartz is abundant; the roundness of the fine sand suggests

that many of the quartz grains classified as igneous are actually reworked sedimentary grains. The 10 per cent content of metamorphic quartz, including lath-shaped schistose quartz and metamorphic quartzite fragments, indicates an ultimate metamorphic terrain for part of the source. The argillaceous rock fragments are mostly shales and phyllites, which would indicate no more than low-rank metamorphism of the source area. These particular varieties of quartz and their relative abundance suggest two sources for the detritus, the largest contributor being a mixed igneous and sedimentary terrain, and the secondary contributor a low-rank metamorphic terrain.

In order to determine geographically the source areas of Chester detritus we must consider the lithology of upper Chester equivalents in the Appalachian geosyncline, the Ouachita trough, and the adjoining platform areas (fig. 5). The Mauch Chunk and Pennington formations, the upper Chester equivalents in Pennsylvania and West Virginia, contain some coarse clastic material, but are composed chiefly of shale and silt on the western side of the geosynclinal axis. The Leitchfield formation, which crops out on the western flank of the Cincinnati arch in the easternmost extension of the Eastern Interior Basin, consists almost entirely of limestone and shale and contains only very subordinate amounts of silt and fine sand. In the southern Appalachians, upper Chester equivalents contain less coarse clastic material than shale and limestone. Recent subsurface investigations seem to indicate that there is no great thickness of sandstone in the upper Chester equivalents in northeastern Mississippi.

On the western side of the Mississippi embayment, we find that the upper Chester correlatives on the south flank of the Ozarks, the Fayetteville and Pitkin formations, with the exception of the Wedington sandstone member of the Fayetteville, do not have any significant proportion of coarse clastics. Farther southwest in the Ouachitas, Chester

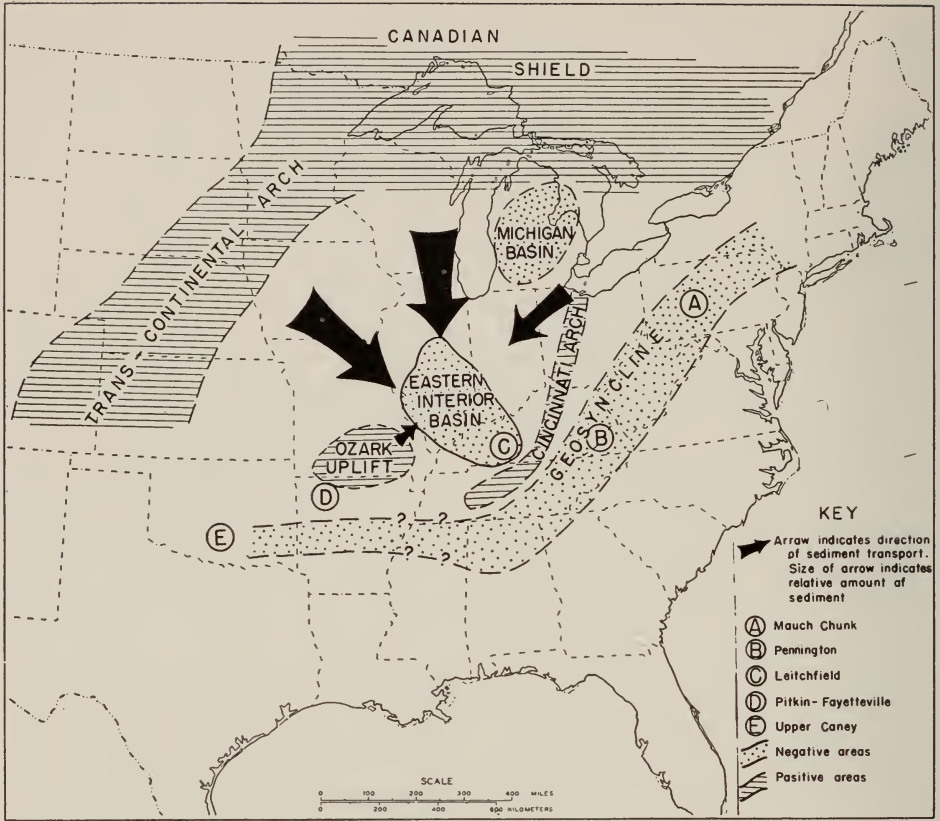


FIG. 5.—Paleogeographic map of upper Chester time.

rocks, the upper Caney and possibly part of the Stanley, are also dominantly fine clastics, although there is a great thickness of greywackes in the Stanley (Bokman, p. 154, 1953) of Oklahoma and Arkansas.

Thus all through the Appalachian geosyncline and in the areas immediately to the west of the downwarp, the outstanding feature of the upper Chester rocks is that they do not contain much sandstone. In those areas of the Ouachitas where there is a great amount of coarse clastics, they are of a greywacke type and not at all similar to the Chester sandstones of Illinois. It is exceedingly doubtful that detritus of greywacke composition would change to detritus of orthoquartzite composition in the course

of a few hundred miles of transport, and therefore it is improbable that Illinois Chester sands were derived from the same areas as lower Stanley greywackes.

The only area aside from Illinois where there may be any great thickness of sandstone of Chester age is in northern Mississippi and Louisiana where Chester strata are deeply buried. This may have been a route through which coarse detritus passed en route to the Eastern Interior Basin, but data are not sufficient to test this possibility. A suggestion that sediments followed any other route to the basin from source areas to the east or south would require that coarse clastics by-passed the geosynclinal downwarps and fine clastics were deposited in them.

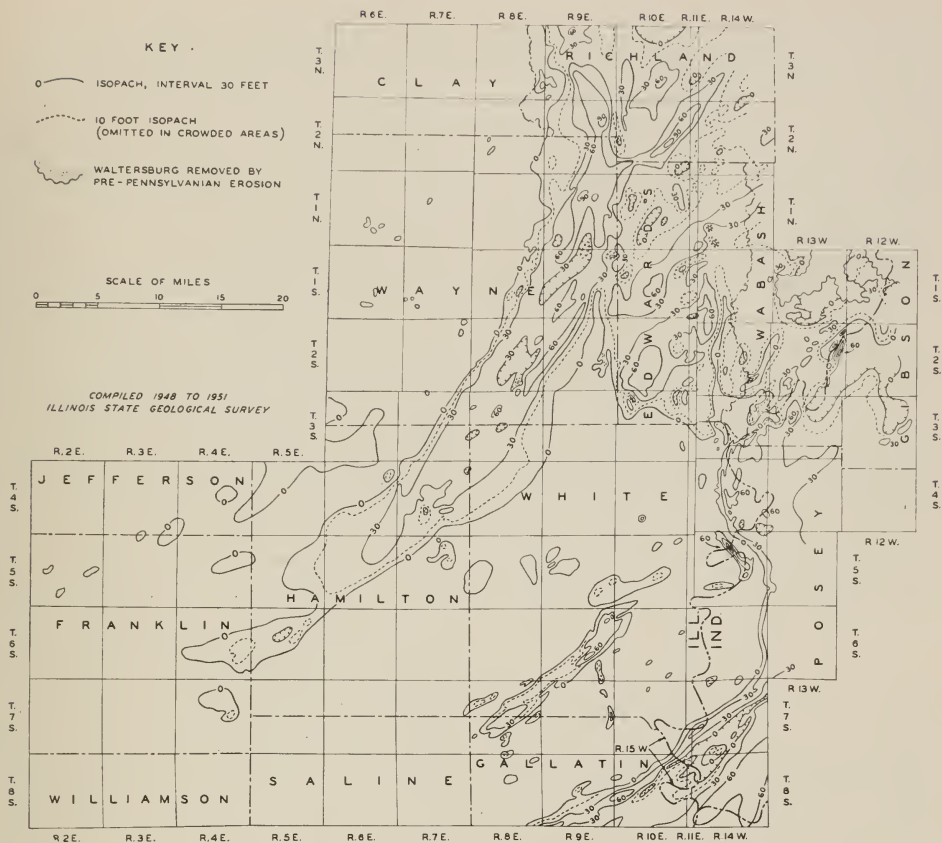


FIG. 6.—Thickness of permeable sand in Waltersburg formation of central Illinois basin (from Swann, 1951).

This explanation runs counter to any normal conditions of sediment transport and deposition. Hence, it is proper to consider the possibility of northern sources within the continent for Chester clastic materials.

One of the first to propose a transcontinental arch, or "Continental backbone," and the Canadian shield as sources for sediments was Levorsen (1931), in his discussion of basal Pennsylvanian sediments. The idea of the arch, unpopular at first, has now been accepted by Eardley (1949), King (1951, p. 30), and others. Reed (1948) has demonstrated the existence of this broad low arch, passing from Minnesota through

central Nebraska and farther south, which never received any Mississippian sediment. Petrographic evidence that Chester sands were derived in large part from pre-existing sediments makes the lower and middle Paleozoic sediments of the transcontinental arch and the Canadian shield likely sources for much of the detritus.

The abundant metamorphic quartz and quartzite in the Indiana samples suggest that there may have been some contribution of this material from the northeast. This area would roughly coincide with the general area which supplied much of the clastic material to the Greenbrier formation in West Vir-

ginia, lower in the Mississippian section (Rittenhouse, 1949, p. 1723). It is interesting, in this connection, to note the isopach map of the Waltersburg sand drawn by Swann (1951) (fig. 6). This map shows several long narrow sand bodies trending northeast-southwest and a broader, more uniformly thick area to the east and north of the linear sand bodies, in Richland, Edwards, and Wabash counties. The thickness distribution of this sand, when considered in the light of probable source areas, suggests that the elongate sand bodies represent accumulations in marine currents that trended roughly transverse to the shoreline; the shoreline trended more or less parallel to the more uniformly thick sand area to the north and east. The latter area was probably the site of near shore deposition, where one could expect to find offshore bars parallel to the shoreline, north-northwest-south-southeast.

TECTONICS

It is important to summarize the tectonics of the basin of deposition which exercised some control on the kind of sediment laid down. During late Mississippian time the Eastern Interior Basin sank slowly and intermittently. Downwarping was more or less uniform as evidenced by generally similar Chester thickness throughout the basin.

However, there were local incipient positive areas at this time, such as the Salem-Louden anticline, the Clay City-Noble anticline, and other smaller anticlinal structures. The presence of these incipient structures, which were more strongly folded in post-Pennsylvanian time, has been amply demonstrated by subsurface investigations in Illinois.

While the subsidence of the basin provided the over-all control on sedimentation, these smaller positive areas exercised some local control. Thus, we find that the total section of many formations thins slightly over the structures. In some places, sandstones are more winnowed and reworked over the structures. The more reworked character of the sands as well as the greater thickness of sand on the structure, noted in several areas, implies that the incipient structures were expressed topographically. The topographic expression caused more turbulence in the water, and the currents were more competent to transport coarse-grained material, which resulted in better sorting of the coarse clastics. In general, the structures were too small to influence sedimentation over a large area.

The petrographic nature of these sandstones, orthoquartzites, subgreywackes, and washed subgreywackes, implies only moderate deformation of the source area. The lack of appreciable quantities of feldspar, the sedimentary varieties of quartz, the fine-grained, rounded, and well-sorted detritus indicate that land areas were not subject to rapid and rigorous erosion and that they were still largely covered by a thin sedimentary mantle. The evidence points to a condition of only moderate uplift, perhaps accompanied by slight deformation.

It is hoped that, in the future, detailed, quantitative petrographic studies of Chester rocks in other areas will be made and correlated with detailed stratigraphic information. Through such studies will come a fuller understanding of the paleogeography, the sedimentation conditions, and tectonic controls under which these rocks were laid down.

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